

**TUMBLEWEED: WIND-PROPELLED SURFICIAL MEASUREMENTS FOR ASTROBIOLOGY AND PLANETARY SCIENCE.** K. R. Kuhlman<sup>1</sup>, A. E. Behar<sup>1</sup>, J. A. Jones<sup>1</sup>, F. Carsey<sup>1</sup>, M. Coleman<sup>1</sup>, G. Bearman<sup>1</sup>, M. Buehler<sup>1</sup>, P. J. Boston<sup>3</sup>, C. P. McKay<sup>3</sup>, L. Rothschild<sup>3</sup>, J. Antol<sup>4</sup>, G. A. Hajos<sup>4</sup>, W. C. Kelliher<sup>4</sup>, I. A. Carlsberg<sup>4</sup>, J. Parker<sup>4</sup>, M. Rudisill<sup>4</sup>, R. L. Crawford<sup>5</sup>, <sup>1</sup>Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA 91109 USA, kkuhlman@jpl.nasa.gov, <sup>2</sup>New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, NM 87801 USA, <sup>3</sup>NASA Ames Research Center, Moffett Field, CA 94035 USA, <sup>4</sup>NASA Langley Research Center, Hampton, VA 23681-2199 USA, <sup>5</sup>Environmental Biotechnology Institute, University of Idaho, Moscow, ID 83844-1052, USA

**Introduction:** Tumbleweed is a wind-propelled long-range vehicle based on well-developed and tested technology (Figure 1 and Figure 2 [1], instrumented to perform surveys Mars analog environments for habitability and suitable for a variety of missions on Mars. Tumbleweeds are light-weight and relatively inexpensive, making it very attractive for multiple deployments or piggy-backing on a larger mission. Tumbleweeds with rigid structures are also being developed for similar applications (Figure 3) [2]. Modeling and testing have shown that a 6 meter diameter Tumbleweed is capable of climbing 25° hills, traveling over 1 meter diameter boulders, and ranging over a thousand kilometers. Tumbleweeds have a potential payload capability of about 10 kg with approximately 10-20W of power. Stopping for science investigations can also be accomplished using partial deflation or other braking mechanisms.

**Astrobiology Surveys:** A Tumbleweed is capable of performing autonomous long-duration surveys of habitability over large areas on Earth. Two terrestrial field sites have been proposed for study: 1) the Atacama Desert in Chile, and 2) the McMurdo Dry Valleys, Antarctica. Both sites are well studied at a limited number of locations, but neither has been mapped for variations in habitability.

Variations in moisture, biologically relevant gases, and the presence of biology can be mapped using simple low mass and low power instruments and an onboard global positioning system (GPS). Data is currently relayed back to JPL via an Iridium modem (Figure 4). The simple measurements performed by Tumbleweed will be followed by more sensitive measurements along the route tracked using the GPS. Many of the desired instruments for both Earth and planetary science are currently under development for in-situ applications, but have not yet been miniaturized to the point where they can be integrated into Tumbleweed. It is anticipated that within a few years, instruments such as gas chromatograph mass spectrometers (GC-MS), quantum cascade tunable diode laser (QC-TDL) gas sensors and ground-penetrating radar (GPR) will be deployable on a Tumbleweed. Portable instruments, such as

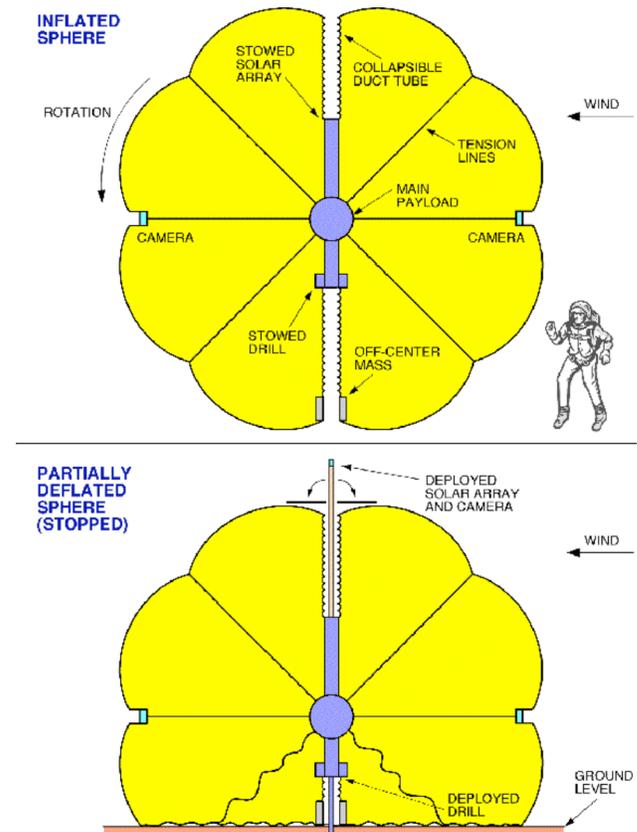


Figure 1. An inflatable Tumbleweed can be stopped to partially deflating the ball and pulling on one of the central payload tension cords to created a “turtle effect.”

a gas chromatograph (GC) and a GPR will be used to simulate the capabilities of future Tumbleweeds and provide more detailed measurements at locations where Tumbleweed measurements indicate heterogeneities. Further, samples will be collected along the route taken by Tumbleweed for extensive laboratory analysis, including characterization of the bioload and biodiversity of each of the samples collected [3]. The results of the Tumbleweed measurements, the field measurements and laboratory analyses will be correlated to verify the current life detection strategy, “follow the water [4].”

**Other Applications of Tumbleweeds:** In addition to surveys for astrobiology, Tumbleweeds can

also be instrumented for investigation of the variation of soil properties and potential resources for use during human exploration across wide areas. Tumbleweeds are also being considered for use underwater and in extraterrestrial atmospheres using neutral buoyancy.

**References:** [1] Behar, A., F. Carsey, J. Matthews, et al. (2004) IEEE Aerospace Conference, Big Sky, Montana. [2] Carsey, F., P. J. Boston, L. J. Rothschild, et al. (2004) "Tumbleweed: Wind Driven Sampling on the Surface of Mars," International Journal of Astrobiology, (S1) 85-86. [3] Kuhlman, K. R., M. T. LaDuc, G.M. Kuhlman, et al. (2004) *Applied and Environmental Microbiology*, to be submitted. [4] Farmer, J., D. Nelson, R. Greeley, et al. (2001) First Landing Site Workshop for MER 2003, NASA Ames Research Center, Moffett Field CA.



Figure 2. The JPL inflatable Tumbleweed deployed in Antarctica [1].



Figure 3. NASA Langley Research Center structured tumbleweed concept [2].

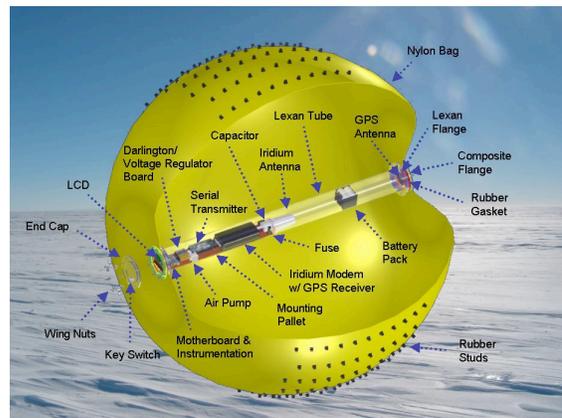


Figure 4. Schematic view of an inflatable Tumbleweed as tested in Greenland and Antarctica [1].